

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
4 April 2002 (04.04.2002)

PCT

(10) International Publication Number  
**WO 02/26531 A2**

- (51) International Patent Classification<sup>7</sup>: **B60R 21/01** (IT). REICH, Daniel; 54196 Bartram Drive, Macomb, MI 48042 (US). MORRELL, Scott; 9594 Spring Ridge Drive, Walled Lake, MI 48383 (US). KREMER, Maria; Finkenweg 8, 85276 Pfaffenhofen (DE).
- (21) International Application Number: **PCT/US01/30388**
- (22) International Filing Date:  
28 September 2001 (28.09.2001) (74) Agents: **SLENZAK, Laura**; c/o Keller, Elsa, Siemens Corporation, 186 Wood Avenue South, Iselin, NJ 08830 et al. (US).
- (25) Filing Language: **English**
- (26) Publication Language: **English** (81) Designated State (*national*): **JP**.
- (30) Priority Data:  
60/236,456 29 September 2000 (29.09.2000) **US** (84) Designated States (*regional*): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).
- (71) Applicant: **SIEMENS AUTOMOTIVE CORPORATION** [US/US]; 2400 Executive Hill Drive, Auburn Hills, MI 48326-2980 (US). **Published:**  
— *without international search report and to be republished upon receipt of that report*
- (72) Inventors: **LICHTINGER, Harald**; 2648 Beacon Hill Court, Apt. 308, Auburn Hills, MI 48326 (US). **CURTIS, Brian, M.**; 3285 Regency Drive, Orion, MI 48359 (US). **GRAF, Robert**; Innerpichl 30, I-39030 Pichl/Gsies
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*



(54) Title: **WEIGHT CLASSIFICATION SYSTEM**

(57) Abstract: A method and apparatus is provided that classifies a seat occupant into one of several different weight classes based on an estimated value of the seat occupant weight. An occupant's measured weight varies when the occupant's seating position changes or when the vehicle travels over adverse road conditions. A plurality of weight sensors are used to measure the weight exerted by a seat occupant against a seat bottom and are used to determine center of gravity for the seat occupant. A seat belt force sensor is also used to assist in classifying the seat occupant. Compensation factors using the seat belt force and center of gravity information are used to generate an estimated weight value. The estimated value of the occupant weight is compared to a series of upper and lower weight thresholds assigned to each of the weight classes to generate an occupant weight sample class. Over a period of time. Several estimated weight values are compared to the weight class thresholds. Once a predetermined number of consistent and consecutive occupant weight sample classes is achieved, the occupant is locked into a specific occupant weight class. When the weight class is locked, the separation value between the upper and lower thresholds is increased to account for minor weight variations due to adverse road conditions and changes in occupant position.

**WO 02/26531 A2**

## WEIGHT CLASSIFICATION SYSTEM

### BACKGROUND OF THE INVENTION

#### Field of the Invention.

- 5           This invention relates to a method and apparatus for measuring the weight of a seat occupant and classifying the occupant into a weight class.

#### Related Art.

- 10           Most vehicles include airbags and seatbelt restraint systems that work together to protect the driver and passengers from experiencing serious injuries due to high-speed collisions. It is important to control the deployment force of the airbags based on the size of the driver or the passenger. When an adult is seated on the vehicle seat, the airbag should be deployed in a normal manner. If there is an infant seat or small adult/child secured to the vehicle seat then the airbag should not be deployed or should  
15   be deployed at a significantly lower deployment force. One way to control the airbag deployment is to monitor the weight of the seat occupant.

- Current systems for measuring the weight of a seat occupant are complex and expensive. These systems use various types of sensors and mounting configurations to determine seat occupant weight. For example, some systems use pressure sensitive  
20   foil mats or a plurality of individual sensors mounted within a seat bottom foam cushion while other systems mount sensors on seat tracks, seat frame members, or other seat structural members. The combined output from the sensors is used to determine the weight of the seat occupant. The accuracy of the weight measurements from these types of sensor systems can be compromised due to additional seat forces  
25   resulting from the occupant being secured to the seat with a seatbelt.

- For example, weight sensor systems can have difficulty identifying an adult, a child, or a car seat when the seatbelt is being used. When a child seat is secured to a seat with a seatbelt, an excess force acts on the sensors mounted within the rear portion of the seat bottom, which interferes with accurate weight sensing. Over tightening of  
30   the seatbelt to securely hold the child seat in place, pulls the child seat down against the rear part of the seat bottom, causing the excessive force measured by the sensors.

Due to this effect, the current weight sensing systems have difficulty in discerning between an adult belted to a seat and a child seat secured to the seat with a seatbelt.

In order to address this problem, sensors have been incorporated into the seatbelt to measure the tension force applied to the seatbelt as passengers or a child  
5 seat is secured to the seat. High seatbelt tension forces indicate that a child seat is secured to the seat. One disadvantage with current seat belt force sensors is that it is difficult to get accurate seat belt force measurements. Another disadvantage with current seat belt force sensors is that non-axial loading on the belt can affect the accuracy of the force measurement.

10 Once seat occupant weight force measurements and belt force measurements are taken, the seat occupant is typically classified into a predetermined classification. Some systems attempt to classify seat occupants into predetermined customer-specified classes usually based only on occupant weight. The classification information is then used to modify the deployment of the airbag. These systems do not provide accurate  
15 and consistent classification over a wide range of adverse road conditions and/or occupant seating conditions.

The accuracy of the weight measurements from known sensor systems can also be compromised due to variable seat forces resulting from momentary events such as rough road conditions or seat occupants adjusting seat position, for example. These  
20 types of events can transfer or remove weight from the seat for short periods of time, which affects the accuracy of the system.

Thus, it is desirable to have an improved seat occupant weight measurement and classification system that provides increased accuracy in weight measurement and classification as well as overcoming any other of the above referenced deficiencies  
25 with prior art systems.

### **SUMMARY OF THE INVENTION**

A weight classification system utilizes weight and seat belt force sensors to classify seat occupants into a predetermined weight classification. Preferably, a  
30 plurality of weight force sensors are mounted between a seat bottom and a vehicle structure and a seat belt force sensor is installed within a seat belt assembly. The weight sensors are preferably located at four connecting points for the seat frame and

pick up all distributed forces (positive and/or negative forces) to determine the total weight on the seat and the center of gravity. The center of gravity and total weight determinations are used to classify the seat occupant, which is further used to control deployment of a safety device, such as an airbag.

5           In the preferred embodiment, one weight sensor is mounted at each corner of the seat bottom. Each weight sensor includes a bending element having one end mounted to the seat frame and an opposite end mounted to a vehicle or other seat structure such as a riser, seat track, or vehicle floor, for example. At least one strain gage assembly is mounted on a center portion of the bending element and an integrated  
10           electronics package electrically connects the strain gage to an electronic control unit (ECU) or other similar device. The strain gages measure deflection of the center portion and generate a weight signal that is sent to the ECU.

          Preferably, the bending element includes a top surface and a bottom surface with at least one centrally formed groove in one of the top or bottom surfaces. The  
15           groove extends at least partially along the width of the sensor to localize strain in the center portion. The strain gage is placed on the other of the top or bottom surfaces, in an opposing direction from the groove.

          Output from the sensors near the front of the seat bottom are combined and compared to output from the sensors near the rear of the seat bottom to determine the  
20           center of gravity. The initial seat occupant weight can be adjusted to take into account the center of gravity of the seat occupant. The initial seat occupant weight can also be adjusted to take into account forces exerted on the seat occupant by the seat belt assembly.

          The seat belt sensor includes a load cell with a strain gage that is integrated into  
25           a seat belt mechanism that is used to secure an occupant to a vehicle seat. When the seat belt is tightened, the sensor is pulled into tension and this is measured by the strain gage. The strain gage measurements and signals are sent to the ECU. The ECU uses the information to determine whether a child seat or an adult is secured to the vehicle seat. Further, the seat belt force information is used to adjust the initial seat occupant  
30           weight and is used to properly classify the seat occupant.

          The seat occupant is classified into one of several different weight classes based on an estimated value of the seat occupant weight. Each of the weight classes

has upper and lower thresholds that define the class. Over time, several comparisons are made between the estimated weight and the thresholds of the weight classes and each comparison results in a weight class sample. The seat occupant is assigned a specific weight class designation once a predetermined number of consistent and consecutive weight class samples is achieved. The specific weight class designation remains locked until a certain number of inconsistent weight class samples are observed.

In a disclosed embodiment of this invention, the method for classifying a seat occupant into a weight class includes the following steps. The seat occupant weight is measured resulting in an estimated weight. The estimated weight is compared to a series of weight classes with thresholds to determine a class sample. The previous steps are repeated until a predetermined number of class samples having the same value is achieved and the class sample becomes locked as the occupant weight class.

Additional steps include generating an occupant weight class signal corresponding to the locked occupant weight class, transmitting the occupant weight class signal to a control unit, and modifying deployment of an airbag based on the occupant weight class signal. The weight class is unlocked when a predetermined number inconsistent class samples is observed. When the class is unlocked, the process repeats.

Once the occupant has been classified into a weight class, that class becomes the known class for the next comparison. Preferably, each weight class is assigned an upper threshold and a lower threshold. At each iteration, the estimated weight is compared to the upper and lower thresholds for the last known weight class. The new class sample is designated the same as the last known weight class if the estimated weight is between the upper and lower thresholds for the last known weight class. The sample is set equal to a next higher weight class if the estimated weight is greater than the upper threshold for the last known weight class or the class sample is set equal to a next lower weight class if the estimated weight is less than the lower threshold for the last known weight class.

In one disclosed embodiment, the value of the upper threshold of the class sample is increased by a first predetermined amount and the value of the lower threshold of the class sample is decreased by a second predetermined amount after

the class sample is locked. The upper and lower thresholds are returned to their initial values when the class sample becomes unlocked.

The subject invention uses seat occupant weight and seat belt force measurements in combination with varying weight class thresholds and class sample  
5 histories to produce a more stable, accurate and robust classification process that reduces errors caused by changes in occupant seating position and adverse road conditions. The more accurate classification system is used to generate control signals, which are used to modify airbag deployment.

These and other features of the present invention can be best understood from  
10 the following specification and drawings, the following of which is a brief description.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 is a schematic view showing a vehicle with an airbag system and an occupant sitting in a seat with the airbag in an active state shown in dashed lines.

15 Figure 2 is a front view of a seat and seat belt assembly.

Figure 3 is a top view of a seat belt force sensor.

Figure 4 is a side view of the seat belt force sensor of Figure 3.

Figure 5 is a schematic control diagram of the seat belt force sensor and control system.

20 Figure 6 is an exploded view of a seat assembly incorporation occupant weight sensors.

Figure 7 is a side cross-sectional view of a weight sensor installed in a seat assembly.

Figure 8 is a perspective view of the weight sensor of Figure 7.

25 Figure 9 is a schematic control diagram of the weight sensor and control system.

Figure 10A is a top perspective view of a weight sensor.

Figure 10B is a bottom perspective view of the weight sensor of Figure 10A.

Figure 10C is a side view of the weight sensor of Figure 10A.

30 Figure 10D is a schematic diagram of an electronics package for a weight sensor.

Figure 11 is a graph showing the relationship between track and lock thresholds.

Figure 12 is a flowchart describing the method of determining a weight class sample.

5        Figure 13 is a flowchart describing the tracking and locking processes.

Figure 14 is a schematic diagram of an ECU used in the control system.

Figure 15A is perspective view of the ECU.

Figure 15B is a perspective of the ECU of Figure 15A from an opposing side.

Figure 16 is a flowchart describing the overall control system operation.

10

#### **DETAILED DESCRIPTION OF AN EXEMPLARY EMBODIMENT**

A vehicle includes a vehicle seat assembly, shown generally at 12 in Figure 1, and an airbag system 14. The seat assembly 12 includes a seat back 16 and a seat bottom 18. A vehicle occupant 20 is secured to the seat 12 with a seat belt assembly 22. The vehicle occupant 20 can be an adult, child, or infant in a car seat secured to the seat 12 with the seat belt 22. A tension force  $F_t$  is exerted on the seat belt 22 that represents the force is exerted against the occupant 20 as the belt is tightened. The occupant 20 also exerts a vertical weight force  $F_w$  against the seat bottom 18. The subject weight classification system measures the tension force  $F_t$  and the weight force  $F_w$ , determines the seat occupant weight and center of gravity, and classifies the seat occupant. The classification information is used to control deployment of a safety device, such as an airbag 24.

The airbag system 14 deploys the airbag 24 under certain collision conditions. The deployment force for the airbag 24, shown as deployed in dashed lines in Figure 1, varies depending upon the type of occupant 20 that is belted to the seat 12. When an adult 20 is belted to the vehicle seat 12, the airbag 24 should be deployed in a normal manner shown in Figure 1. If there is small adult or an infant in a car seat secured to the vehicle seat 12 then the airbag 24 should not be deployed or should be deployed at a significantly lower force. Thus, it is important to be able to determine whether there is an adult 20 belted to the seat 12 or whether a small adult or infant seat is secured to the seat with a seat belt 22. One way to determine this is by monitoring the tension exerted on the seat belt 22. When an adult 20 is belted to the

seat, normal seat belt forces are exerted against the seat belt 22. When an infant or child seat is belted to the seat 12, high tension forces are exerted on the seat belt 22 because the seat belt 22 is overtightened to securely hold the child seat in place.

5 The vehicle seat 12 is mounted to a vehicle structure 26, such as the floor, in a manner well known in the art. The subject weight classification system uses a plurality of sensors, some mounted in the seat bottom 18 to measure seat occupant weight and some mounted in the seat belt assembly 22 to measure the seat belt tension force Ft. The output from the sensors that measure seat occupant weight is used to determine an initial seat occupant weight and a seat occupant center of gravity. 10 The center of gravity information along with the output from the sensors that measure seat belt forces is used to generate a compensation factor that is used to adjust the seat occupant weight to take into account variations seat occupant position. The seat occupant is then classified into a predetermined weight classification by a method that filters out momentary events such as rough road 15 conditions or seat occupants adjusting seat position. The preferred sensors for measuring occupant weight and seat belt forces as well as the method for classifying the seat occupants will be discussed in detail below.

The seat belt 22, shown more clearly in Figure 2, has a strap portion 28 that includes a shoulder harness and/or lap belt that is connected to a male buckle member 30. 20 A seat belt latch mechanism 32 is hard mounted to the seat 12 and typically extends outwardly from the seat 12 between the seat back 16 and the seat bottom 18. The latch mechanism 32 includes a female receptacle 34 that receives the male buckle member 30 to secure the occupant 20 or child seat to the seat 12. The strap portion 28 can be manually or automatically tightened once the belt is 25 buckled to a desired tension.

A sensor assembly 40 for measuring the tension forces in the seat belt 22 is shown in Figures 3 and 4. The sensor assembly 40 includes a rigid member that is preferably formed as a metallic plate 42 from 4130Rc39 material, however, other similar materials could also be used. The plate 42 includes a first end 44 that is 30 attached via a loop connection 46 to material that forms a portion of the seat belt 22 and a second end 48 that is attached to a vehicle structure such as a B-pillar or seat latch mechanism 32, 34.



The plate 42 includes a necked portion 50 positioned between the ends 44, 48 that is narrower than the ends 44, 48. A strain gage 52 is mounted on the necked portion 50. The tightening of the seat belt 22 exerts a tension force  $F_T$  on the plate 42 via the looped connection 46, which results in strain on the necked portion 50.

5 The strain gage 52 measures this strain. The strain gage 52 is preferably a full bridge strain gage with four (4) grids.

The first end 44 of the plate 42 is preferably positioned at an angle relative to the necked portion 50 and the second end 48, shown in Figure 4. This causes the tension force to be applied at an angle, which creates a moment  $M_T$  at one edge of the necked portion 50. The second end 48 of the plate 42 is hard mounted to a vehicle structure creating a reaction force  $F_{rea}$  and moment  $M_{rea}$ . The strain gage 52 measures the strain resulting in the necked portion 50 of the plate 42 as the tension force  $F_T$  is applied to the first end 44 of the plate 42.

15 An electrical connector 54 is also mounted on the plate 42 adjacent to the strain gage 52. As shown in Figure 5, the strain measurements are generated as signals 56 that are sent from the gage 52 to the connector 54 and then to an individual electronic control unit (ECU) or microprocessor 58, see Figure 5. The ECU 58 can be incorporated into the connector 54 to include the necessary electronics and printed circuit board (as shown in Figure 3) or can be a separate component at a remote location on the vehicle, as discussed below. The ECU 58 processes the strain signals 56 to determine the magnitude of the tension forces  $F_t$  exerted on the seat belt 22 and sends a seat belt force output signal 66 to a central electronic control unit (ECU) or central microprocessor 60, which uses the seat belt force signal and occupant weight measurements to classify the seat occupant and to ultimately control deployment of the airbag 24. It should be understood that the ECU 58 can be a separate unit or can be incorporated into the central ECU 60.

20 The strain gage 52 measures the strain caused by the tension force  $F_T$  in the seat belt 22 resulting in the generate of the seat belt force output signal 66. The central ECU 60 uses the seat belt force output signal 66 to adjust or compensate the measured seat occupant weight for over-tightened seat belts. Further, the seat belt force output signal 66 can be used to identify a child seat. If the tension force  $F_T$  exceeds a predetermined limit the system identifies a child seat. For example, an

adult can experience a tension force in a seat belt up to approximately 30 pounds (lbs) and still be comfortable. If the strain gage 52 measures a tension force  $F_T$  that exceeds 30 lbs then that would indicate that a child seat has been belted to the seat 12. Once a child seat has been identified as the seat occupant, then the airbag 24  
5 would not be deployed during a collision. It should be understood that 30 lbs is an approximate value, which can vary due to differing seat and seatbelt configurations. Thus, the predetermined limit for comparison to the measured tension force  $F_T$  can also vary depending upon the seat configuration.

The sensor system for measuring seat occupant weight is shown in Figure 6. A  
10 plurality of seat occupant weight sensors 68 are mounted to seat structural member such as a seat frame or track member, generally indicated at 70 in Figure 6.

As discussed above, the seat 12 is preferably mounted to the vehicle structure 26 on an inboard track assembly 70a and an outboard track assembly 70b that is spaced apart from the inboard track assembly 70a by a predetermined  
15 distance. Both the inboard 70a and outboard 70b track assemblies include first 72 and second 74 track members. The first track member 72 is typically mounted to a seat riser 76 or directly to the vehicle structure 26, such as the floor. The second track member 74 is mounted for sliding movement relative to the first track member 72 so that seat 12 position can be adjusted forwardly and rearwardly  
20 within the vehicle to a desired position.

The plurality of sensor assemblies 68 are mounted between the first track members 72 of the inboard 70a and outboard 70b track assemblies and the riser 76. In the preferred embodiment, four (4) sensor assemblies 68 are used with a first sensor assembly 68a positioned near the front of the inboard track assembly  
25 70a, a second sensor assembly 68b positioned near the rear of the inboard track assembly 70a, a third sensor assembly 68c positioned near the front of the outboard track assembly 70b, and a fourth sensor assembly 68d positioned near the rear of the outboard track assembly 70b.

The sensor assemblies 68 are preferably installed as described above, i.e.  
30 between the lower seat track 72 and the riser 76. However, the sensor assemblies 68 can also be installed between the lower seat track 72 and a reinforced floor plan or reinforcement bracket.

Preferably, each sensor assembly 68a (left front portion of seat bottom 18), 68b (left rear portion of seat bottom 18), 68c (right front portion of seat bottom 18), and 68d (right rear portion of seat bottom 18) has a first end 78 mounted to the first track member 72 with at least one fastener 80 and a second end 82 mounted to the riser 76 with at least one fastener 80, as shown in Figure 7. It should be understood that any type of fastener can be used and that other joining methods known in the art can also be used to mount the sensors 68, however, M10 fasteners are preferred. A central bendable portion 84 extends between the first 78 and second 82 ends of the sensor assembly 68. As the vertical force  $F_w$  of the seat occupant 20 is exerted on the seat bottom 18, the central bendable portion 84 of each sensor assembly 68a, 68b, 68c, 68d deflects or bends into an S-shaped configuration putting one portion of the sensor 68 in compression and another portion in tension.

As shown in Figures 7 and 8, the first 78 and second 82 ends are raised above/below the central bendable portion 84 to form steps 86 on each side of the central bendable portion 84. The height of the steps 86 can be varied. This configuration forms gaps between the sensor 68 and the track member 72 and between the sensor 68 and the riser 76 to facilitate bending.

A strain gage 88 is mounted to each of the sensors 68a, 68b, 68c, 68d to measure the amount of bending in the central portion 84. The sensors 68 have a top surface 90 facing the seat bottom 18 and a bottom surface 92 facing the riser 76. Preferably, a combination of four (4) strain gages, forming a full bridge, are mounted on one of the top 90 or bottom 92 surfaces to measure the bending. The four strain gates are thus combined to serve as a Wheatstone Bridge for measuring deflection. The operation of a Wheatstone Bridge is well known in the art.

As shown in Figure 8, the strain gage 88 is mounted on the top surface 90 of the sensor 68. A first aperture 94 is formed at the first end 78 of the sensor 68 and a second aperture 96 is formed at the second end 82 of the sensor 68 for receiving the fasteners 80. The strain gage 88 is positioned between the apertures 94, 96 on the top surface 90. In order to achieve more accurate readings, full-bridge strain gage 88 should have all strain gage components mounted on only one surface of the sensor 68. In other words, if the strain gage 88 is mounted on the

top surface 90 then no strain gage components should be mounted on the bottom surface 92 or if the gage 88 is mounted on the bottom surface 92, then no strain gage components should be mounted on the top surface 90.

Preferably, the sensors 68 are capable of a measuring range of -100 kilograms to +100 kilograms with a resolution of .1 kilograms. Further the sensors 68 are preferably designed to withstand 1500 pounds of force without performance degradation.

The sensors 68a, 68b, 68c, 68d each generate a signal representative of the occupant weight that causes bending at the respective location of the sensors 68a, 68b, 68c, 68d, see Figure 9. Thus, the first sensor 68a generates a first signal 100, the second sensor 68b generates a second signal 102, the third sensor 68c generates a third signal 104, and the fourth sensor 68d generates a fourth signal 106. The signals 100, 102, 104, 106 are transmitted to a common interface unit 108 and are then fed into the central processor unit or electronic control unit (ECU) 60 as is known in the art. The sensors 68a, 68b, 68c, 68d output an amplified and digitized signal to the ECU 60 for final signal conditioning. The ECU 60 combines the signals 100, 102, 104, 106 to determine the total weight of the occupant 20.

The sensors 68 can be susceptible to errors that can distort the weight measurement. Changes in temperature can result in base material expansion, resistance changes, and bonding changes. Further there can be initial offset error and part-to-part variation between the bendable portion 84 and the strain gage 88 can affect gain. To reduce these errors, the strain gage 88 is preferably encapsulated, and the bendable portion 84 is designed to provide as much signal output as possible, the design of which will be discussed in further detail below.

Each sensor 68 includes an electronics package 140 that has a flexible printed circuit board (PCB) 142 and an application specific integrated circuit (ASIC) 144, shown in Figure 10D. This package 140 can be used with the sensor 110 shown in Figures 10A-D or the sensor 68 shown in Figures 7 and 8. To further reduce sensor error, decoupling and differential capacitance is provided at the PCB 142. The sensor signal conditioning ASIC 144 is used to provide initial offset compensation and to measure temperature for temperature compensation in

the ECU 60. In addition to these features, the ASIC 144 provides amplification, signal analog to digital conversion, compensation parameter storage, serial communication of load signal, and diagnostics.

Each sensor 68 and electronics package 140 is preferably assembled in the following manner. The surface of the sensor 68 is prepped. Cables are bonded in a flexible-strip connector 146, which is attached to the strain gage 88. The flexible-strip connector 146 and strain gage 88 are bonded to the bendable portion 84. The flexible-strip connector 146 is soldered to a housing 148 that surrounds the PCB 142 and ASIC 144. The strain gage 88 is preconditioned as is known in the art and the PCB 142 is attached into the housing 148 with press-fit pins (not shown). A cover (not shown) is welded onto the housing 148 and the sensor 68 is calibrated.

As discussed above, the ECU 60 combines the weight sensor signals 100, 102, 104, 106 to determine the total weight of the occupant 20. The left front sensor 68a and the right front sensor 68c are combined to determine a front weight portion and the left rear sensor 68b and right rear sensor 68d are combined to determine a rear weight portion. The front and rear weight portions are compared to determine the center of gravity. The total weight of the seat occupant 20 can then be adjusted by the ECU 60 to account for variations due to the center of gravity position of the occupant. Further the ECU 60 can adjust or compensate for seat belt forces acting on the seat occupant 20 as discussed above.

A preferred embodiment of a weight sensor 110 is shown in Figures 10A-10C. In this preferred embodiment, each of the sensor assemblies 110a, 110b, 110c, 110d includes at least one groove 112 formed in one of the top 90 or bottom 94 surfaces of the sensor 110. The groove 112 extends at least partially along the width of the sensor assembly 68 to localize strain in the central bendable portion 84. The full bridge strain gage 88 is placed on the opposing surface, facing an opposite direction from the groove 112, see Figure 10B. As shown, the groove 112 preferably extends across the entire width of the sensor 68.

By measuring the deflection in all four (4) locations in the inboard 70a and outboard 70b track assemblies, it is possible to calculate the occupant weight, which is proportional to the sum of the output of all of the sensors 68a, 68b, 68c,

68d. The electronics for signal conditioning and the interface 108 can be housed within the track assemblies 70a, 70b as is well known in the art.

Once the weight and seatbelt forces have been measured, the occupant 20 is placed into a weight classification. The weight signals 100, 102, 104, 106 are combined and initially represent an estimated weight signal 114 for the occupant 20. The ECU 60 compares the weight signal 114 to a series of weight classes each having at least one threshold value, assigns a weight class designation to the occupant 20, and generates an output control signal 116 that controls and modifies deployment of the airbag 24 based on the weight classification. The classification process will be discussed in greater detail below.

The weight sensors 68 are preferably calibrated prior to installation. Mounting the seat 12 in the vehicle induces stresses in the seat track assemblies 26 that are then seen in the sensors 68. These stresses can vary from seat to seat and represent an offset value. During system diagnostics, the sensors 68 can be re-calibrated. To re-calibrate, the seat 12 must be empty. Once sensor output is stabilized, the zero values are then restored. This procedure can also be used to compensate for sensor wear that occurs over time.

As discussed above, the ECU 60 (shown schematically in Figure 14) receives signals from the weight sensors 68 and the seat belt force sensor 40 and uses this information to classify seat occupants 20. The ECU 60 includes three (3) main sections: power regulation 60a, microprocessing 60b, and communication 60c. The signals 66, 100, 102, 104, 106 are received and processed by the ECU 60 to make an approximation of the weight classification. After the ECU 60 makes a determination, a message is placed on a communications bus for the vehicle to use properly. Diagnostics are periodically performed to check the functionality of such components as the microprocessor, the sensors 40, 68, communication bus, input voltage, etc., for example.

After power down, the ECU 60 preferably stays alive to perform system calibration to adjust for offset that may occur over time. The ECU 60 can put itself and the sensors 40, 68 to sleep after calibrations are completed to conserve vehicle energy.

As shown in Figures 15A and 15B, the ECU 60 preferably includes a plastic housing 120 with integrated insert molded sealed connectors 122 for attachment/connection to the sensors 40, 68. These types of connectors 122 simplify installation and interface connections.

5       The weight measurements taken by the sensors 68 can vary as the occupant  
20 changes seating positions and can vary as the vehicle travels through various  
maneuvers and over different types of roads. In order to provide a consistent and  
accurate weight classification, the classification process must filter out these  
variations. The subject invention monitors the occupant's estimated weight and  
10 compares the estimated weight to a series of weight class thresholds to determine an  
individual classification sample. A history of these class samples is observed and  
recorded by the ECU 60. Once a predetermined number of consistent and  
consecutive samples are observed, the class sample is locked as the occupant's  
weight class. Over time, a plurality of comparisons are made between the estimated  
15 weight and the weight class thresholds.

Each weight class is assigned a predetermined upper threshold and a  
predetermined lower threshold. The number and values for the upper and lower  
thresholds can be varied. Each weight class sample is determined by comparing the  
occupant's estimated weight against the previous weight class sample's thresholds.  
20 If the estimated weight falls between the upper and lower thresholds for that  
previous class, the current class sample is set to that last sample. If the estimated  
weight does not fall between the upper and lower thresholds for that previous class,  
either the weight class above or the weight class below the previous weight class is  
set for the current weight class depending on which threshold is crossed. Preferably,  
25 only one incremental weight class change is permitted for each iteration. Allowing a  
change of only one class per iteration helps to smooth the transition between the  
classes.

The upper and lower thresholds for each class varies depending on whether  
the process is in the track mode or the lock mode. If the system is locked onto a  
30 specific weight class, the separation between the upper and lower thresholds for that  
weight class is increased to provide more hysteresis. By increasing the hysteresis  
when locked, it is more difficult to change or unlock the weight class designation.

This helps to filter out unintended weight class changes, i.e., error induced by adverse road conditions or changes in occupant seating position. Figure 11 shows the relationship between the track and lock thresholds. Note that the track upper and lower thresholds for weight class two (2) are closer together than the lock upper and lower thresholds for weight class two (2). Thus, the upper threshold for weight class (2) is increased and the lower threshold is decreased when class (2) is the locked class.

Figure 12 is a flow chart showing the process for determining the current weight class sample. When the process is started, there is a determination of whether the process is in the track or lock mode. If the process is in the track mode than the current estimated weight is compared to the previous class' track lower threshold. If the current estimated weight is less than the previous class' track lower threshold than the next lower weight class is set as the current weight class. If the current estimated weight is not less than the previous class' track lower threshold than the estimated weight is compared to the previous class' track upper threshold. If the current estimated weight is greater than the previous class' track upper threshold than the next higher weight class is set as the current weight class. If the current estimated weight is not greater than the previous class' track upper threshold than the current weight class is the same as the previous weight class. A similar method is used when the process is in the lock mode except the current estimated weight is compared to the previous class' lock upper and lower thresholds.

As the process moves through each iteration, a history of the comparisons between the estimated weight and the weight class thresholds is observed and recorded, see Figure 13. The weight class samples are monitored, looking for the same class sample to be repeated. The process starts counting or tracks consecutive samples of the same weight class. If a non-consistent sample is observed, the count is reset to zero. When a predetermined number of consistent and consecutive samples is observed, that observed weight class becomes locked. Once a class is locked, it remains the designated occupant weight class until a specific number of consecutive weight class samples above or below the locked class is observed. If the lock is lost, the process starts tracking the number of consecutive weight classes again and the process is repeated. The output is either the tracked or locked weight



class, depending on the mode. If a class is locked, the locked class is the output class. If a class is not locked, the track weight class is the output class. The track/lock feature helps to filter out class changes caused by occupants 20 that change position, class changes caused by adverse road conditions, and class changes  
5 resulting from sudden vehicle maneuvers such as turning or braking.

Preferably, the class update rate is approximately one update every second and the weight class locking delay is at least five (5) seconds. Preferably the locking delay is approximately between five (5) and seven (7) seconds. This delay period filters out momentary events that may transfer or remove weight from the seat, e.g.,  
10 due to rough road conditions or seat occupant body movements. These momentary events are typically important for borderline cases. If the same weight class is calculated for five to seven seconds the class is locked. This widens the window for the determination of the current weight class. A weight outside of the window must be maintained for five to seven seconds to unlock and change the weight class.  
15 These times can be adjusted through calibration. An unlocked system can change weight classes every second. While these are the preferred time periods, it should be understood that these time periods could vary depending on the application.

A flowchart summarizing the weight classification system is shown in Figure 16. The weight sensors 68a-d generate weight signals 102-106 that are proportionate  
20 to the weight exerted against the seat bottom 18 at the respective sensor location. The front sensors 68a, 68c are combined to determine a front weight portion signal 130 and the rear sensors 68b, 68d are combined to determine a rear weight portion signal 132. The front 130 and rear 132 weight portion signals are compared to determine a center of gravity. An estimated seat occupant weight is then determined  
25 by using various compensation factors including information from the seat belt force sensor 40, center of gravity, and combined weight information from all weight sensors 68a-d. This adjusted weight designation is then used to classify the seat occupant by a process discussed above.

The number of classes and thresholds can be correlated to predetermined  
30 requirements that vary according to different specifications and vehicle types. One example of a set of weight classes is as follows. If the weight determination is less than 8 kilograms the seat is determined to be empty, if the weight determination is

between 8 and 30 kilograms the system indicates a child is the seat occupant, if the weight determination is between 30 and 60 kilograms the system indicates a small adult is the seat occupant, and if the weight determination is greater than 60 kilograms the system indicates a large adult is the seat occupant.

- 5        Although a preferred embodiment of this invention has been disclosed, it should be understood that a worker of ordinary skill in the art would recognize many modifications come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

## CLAIMS

1. A vehicle weight classification system comprising:
  - a seat assembly having a seat frame for supporting a seat bottom;
  - 5 a seat belt assembly for securing a seat occupant to said seat assembly;
  - a plurality of weight sensors mounted to said seat frame for generating
  - a plurality of weight signals in response to a weight force applied to said seat bottom;
  - at least one seat belt force sensor for generating a seat belt force signal;
  - an electronic control unit for receiving said weight signals and seat belt
  - 10 force signals to determine occupant weight and center of gravity, generating an
  - occupant classification based on said occupant weight and center of gravity, and
  - transmitting an output control signal based on said occupant classification; and
  - an airbag module for receiving said output control signal to control
  - airbag deployment based on said occupant classification.
- 15 2. A system according to claim 1 wherein said seat assembly includes a seat mount for attachment to a vehicle floor and said plurality of weight sensors comprises a first sensor mounted at a front right side corner of said seat bottom between said seat frame and said seat mount, a second sensor mounted at a front left
- 20 side corner of said seat bottom between said seat frame and said seat mount, a third sensor mounted at a rear right side corner of said seat bottom between said seat frame and said seat mount, and a fourth sensor mounted at a rear left side corner of said seat bottom between said seat frame and said seat mount.
- 25 3. A system according to claim 2 wherein said plurality of weight signals comprises a first weight signal generated by said first sensor, a second weight signal generated by said second sensor, a third weight signal generated by said third sensor, and a fourth weight signal generated by said fourth sensor, said first and second weight signals being combined to produce a front weight portion signal and
- 30 said third and fourth weight signals being combined to produce a rear weight portion signal wherein said front and rear weight portion signals are compared to each other to determine said center of gravity.

4. A system according to claim 3 wherein said front and rear weight portion signals are combined to produce an initial seat occupant weight and wherein said electronic control unit modifies said initial seat occupant weight based on said seat belt force signal and said center of gravity to produce a final seat occupant weight,  
5 said output control signal being generated based on said final seat occupant weight.

5. A system according to claim 2 wherein each of said weight sensors includes a bending element mounted between said seat frame and said seat mount, at least one strain gage assembly mounted on said bending element, and an integrated  
10 electronics package for electrically connecting said strain gage to said electronic control unit.

6. A system according to claim 5 wherein said electronics package includes flexible printed circuit board mounted to said bending element and an  
15 application specific integrated circuit supported by said bending element for conditioning said weight signal.

7. A system according to claim 5 wherein said bending element includes a first end mountable to said seat frame, a second end mountable to said seat mount,  
20 and a bendable center portion having an upper surface and a lower surface wherein a groove is formed in one of said upper or lower surfaces extending along the width of said bending element to localize strain in said bendable center portion.

8. A system according to claim 7 wherein said strain gage assembly is  
25 mounted on the other of said upper or lower surfaces, facing opposite from said groove.

9. A system according to claim 5 wherein said electronic control unit includes a power regulator connectible to a power source, a microprocessor for  
30 analyzing said weight signals and said seat belt force signals, and a communication bus for interacting with said airbag control module.

10. A system according to claim 9 wherein said electronic control unit includes a plastic housing having integrated insert molded sealed connectors for connection to said power source and said electronics package.

5 11. A system according to claim 9 including a series of weight class data storable in said electronic control unit wherein each weight class has an upper threshold and a lower threshold wherein said microprocessor for generates an estimated weight signal based on the combination of said plurality of weight signals, compares said estimated weight signal to said upper and lower thresholds to assign  
10 said signal an appropriate weight class designation, and locks said estimated weight signal into an occupant specific weight class when a predetermined number of consistent and consecutive weight class designations is achieved.

12. A system according to claim 2 wherein said seat belt assembly includes  
15 a rigid member having a first end for supporting a seat belt portion and a second end for attachment to a vehicle structure and wherein said at least one seat belt force sensor comprises at least one strain gage assembly mounted on said rigid member between said first and second ends for measuring the strain exerted on said rigid member by a tension force applied to said seat belt portion.

20 13. A system according to claim 12 including an electrical connector mounted to said rigid member adjacent to said strain gage for receiving strain measurements from said strain gage and transmitting said measurements to said electronic control unit to determine the magnitude of the tension force.

25 14. A system according to claim 13 wherein said rigid member includes a neck portion positioned between said first and second ends having a width that is less than the width of said first and second ends and wherein said strain gage is mounted on said neck portion.

30

15. A system according to claim 14 wherein said first end includes an elongated slot for a loop attachment to said seat belt portion and said second end includes at least one aperture for receiving a fastener for attachment to the vehicle structure and wherein said electrical connector is mounted to said rigid member  
5 adjacent to said second end between said aperture and said neck portion.

16. A method for classifying a seat occupant into a weight class comprising the steps of:

- 10 (a) measuring a weight force of a seat occupant exerted against a seat bottom to generate a weight signal;
- (b) measuring a seat belt force generated by securing the seat occupant to a vehicle seat with a seat belt assembly to generate a seat belt force signal;
- (c) determining center of gravity of the seat occupant based on said weight signal;
- 15 (d) classifying the seat occupant into a predetermined weight classification based on said weight and seat belt force signals;
- (e) generating an output control signal based on seat occupant classification; and
- (f) controlling deployment of a safety device based via the output  
20 control signal.

17. A method according to claim 16 wherein step (d) includes
- (d1) generating an estimated weight based on the weight signal;
  - (d2) comparing the estimated weight to a series of weight classes  
25 each having at least one weight class threshold to determine an individual classification sample;
  - (d3) repeating steps (d1) and (d2) until a predetermined number of individual classification samples having the same value is achieved;
  - (d4) locking the individual classification sample as the occupant  
30 weight class; and
  - (d5) generating an occupant weight class signal.

18. A method according to claim 17 further including the steps of

(d6) unlocking the individual classification sample when a predetermined number of non-equal individual classification samples is achieved; and

(d7) returning to step (a) when step (d6) is satisfied.

5

19. The method according to claim 18 wherein step (d2) further includes assigning each weight class an upper threshold and a lower threshold, comparing the estimated weight to the upper and lower thresholds for the last known weight class, and setting the individual classification sample equal to the last known weight class if  
10 the estimated weight is between the upper and lower thresholds for the last known weight class.

20. The method according to claim 19 including the step of setting the individual classification sample equal to a next higher weight class if the estimated  
15 weight is greater than the upper threshold for the last known weight class or setting the individual classification sample equal to a next lower weight class if the estimated weight is less than the lower threshold for the last known weight class.

21. The method according to claim 20 including the steps of increasing  
20 the value of the upper threshold of the individual classification sample by a first predetermined amount and decreasing the value of the lower threshold of the individual classification sample by a second predetermined amount once the individual classification sample is locked.

22. The method according to claim 20 including the steps of decreasing  
25 the value of the upper threshold of the individual classification sample by a first predetermined amount and increasing the value of the lower threshold of the individual classification sample by a second predetermined amount after the individual classification sample is unlocked.

30

23. The method according to claim 18 including the steps of  
providing a track mode having a first set of thresholds for each of the  
weight classes and a lock mode having a second set of thresholds for each of the  
weight classes that is different than the first set of thresholds; and  
5 determining whether the method is in the track mode or the lock  
mode prior to step (d2).

24. The method according to claim 23 including the step of providing the  
first set of thresholds with an upper track threshold and a lower track threshold for  
10 each of the weight classes and providing the second set of thresholds with an upper  
lock threshold having a value greater than the upper track threshold and a lower lock  
threshold having a value less than the lower track threshold.

25. The method according to claim 24 including the step of beginning in  
15 the track mode, initiating the lock mode when a predetermined number of consistent  
and consecutive individual classification samples is achieved, and moving from the  
lock mode to the track mode when a predetermined number of inconsistent  
individual classification samples is achieved.

26. The method according to claim 18 wherein step (d6) further includes  
20 waiting at least five seconds before unlocking the individual classification sample.

27. The method according to claim 17 including the step of filtering out  
momentary events prior to step (d4).  
25

28. The method according to claim 27 wherein step (d3) further includes  
repeating steps (d1) and (d2) for at least five seconds prior to locking the individual  
classification sample.

29. The method according to claim 17 including the step of updating  
30 weight class determination at least one time per second prior to locking the individual  
classification sample.



30. The method according to claim 17 wherein step (a) further includes  
mounting a first sensor at a right front portion of the seat bottom to  
generate a right front weight signal;  
mounting a second sensor at a left front portion of the seat bottom to  
5 generate a left front weight signal;  
mounting a third sensor at a right rear portion of the seat bottom to  
generate a right rear weight signal;  
mounting a fourth sensor at a left rear portion of the seat bottom to  
generate a left rear weight signal; and  
10 generating the estimated weight based on the right front, left front, right  
rear, and left rear weight signals.

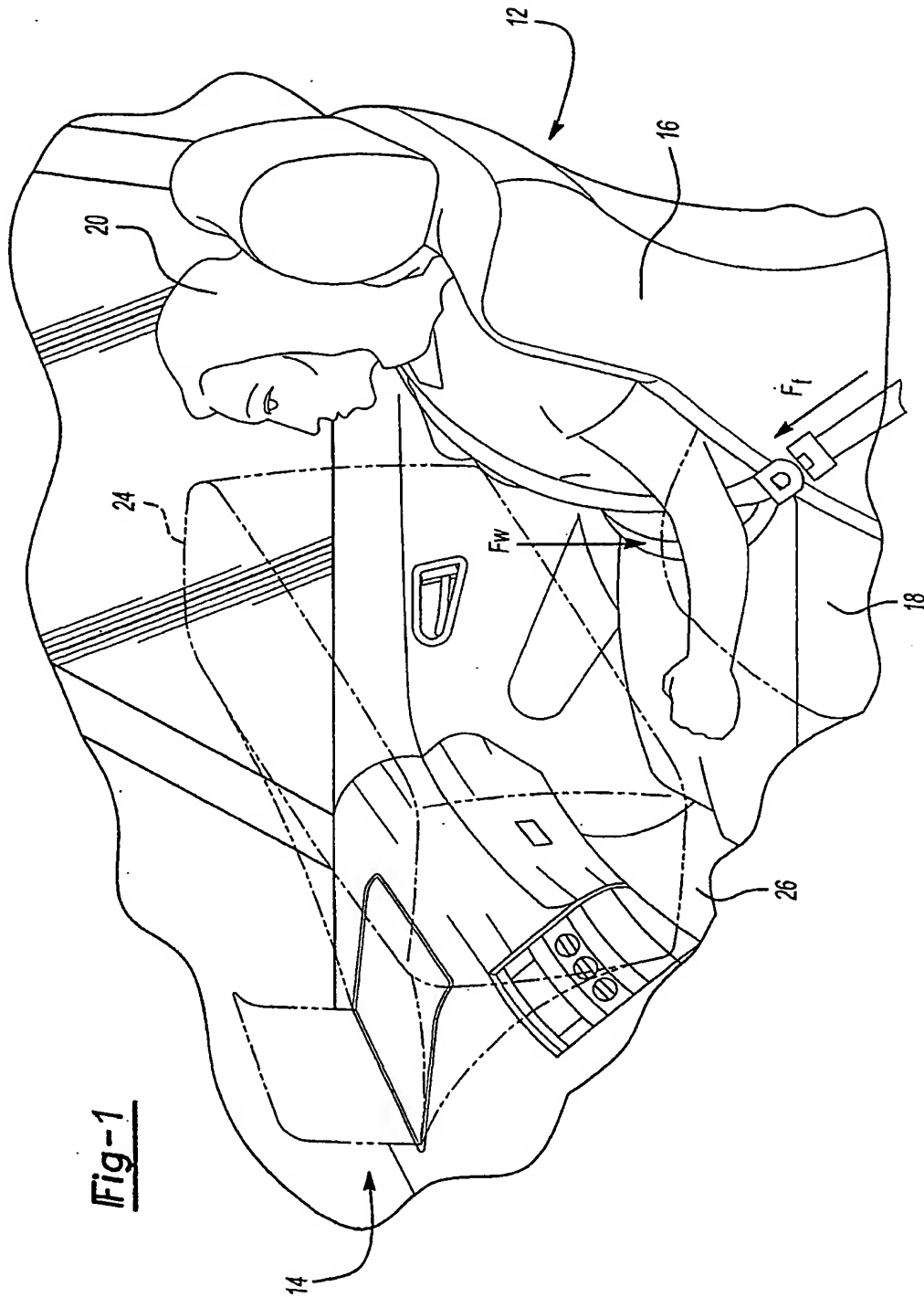
31. The method according to claim 30 wherein step (c) further includes  
combining the right front and left front weight signals to generate a front weight  
15 portion signal and combining the right rear and left rear weight signals to generate a  
rear weight portion signal, and comparing the front and rear weight portion signals to  
each other to determine the center of gravity.

32. The method according to claim 31 including the step of generating a  
20 first weight compensation factor based on the seat belt force signal.

33. The method according to claim 32 including the steps of generating a  
second weight compensation factor based on the center of gravity and adjusting the  
estimated weight via the first and second weight compensation factors to determine  
25 an adjusted seat occupant weight.

34. The method according to claim 33 wherein the adjusted seat occupant  
weight is determined prior to locking the individual classification sample.

1/10



2/10

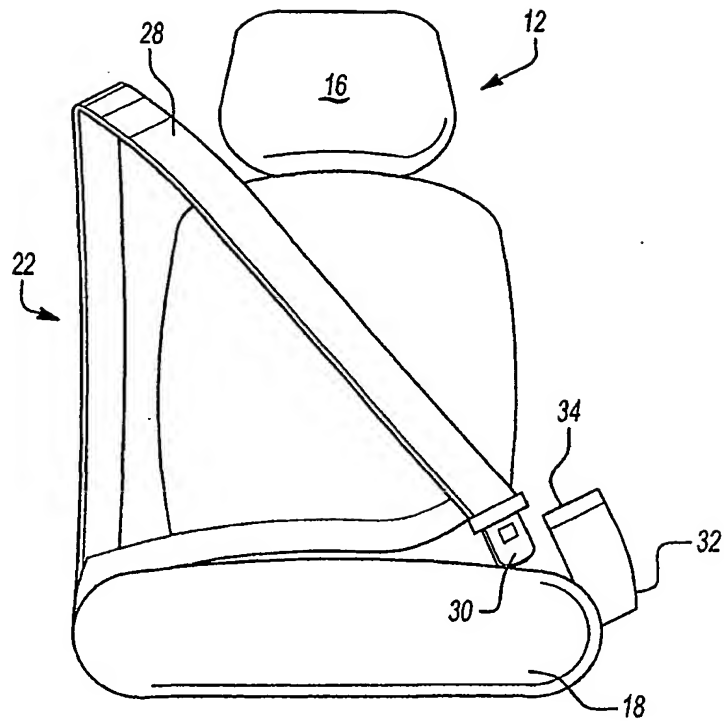


Fig-2

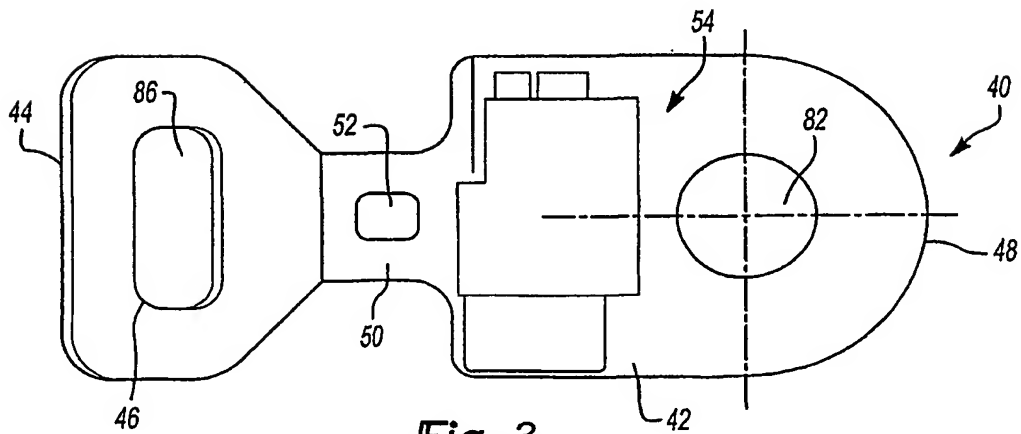
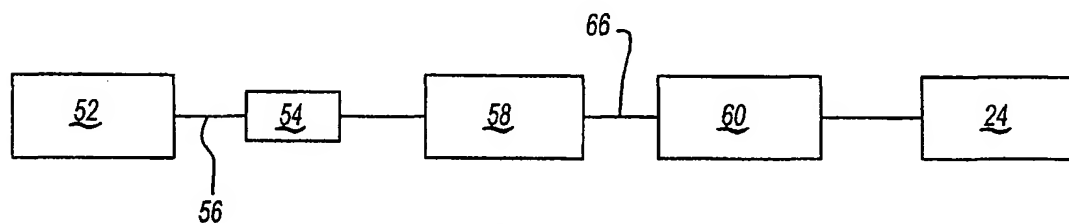
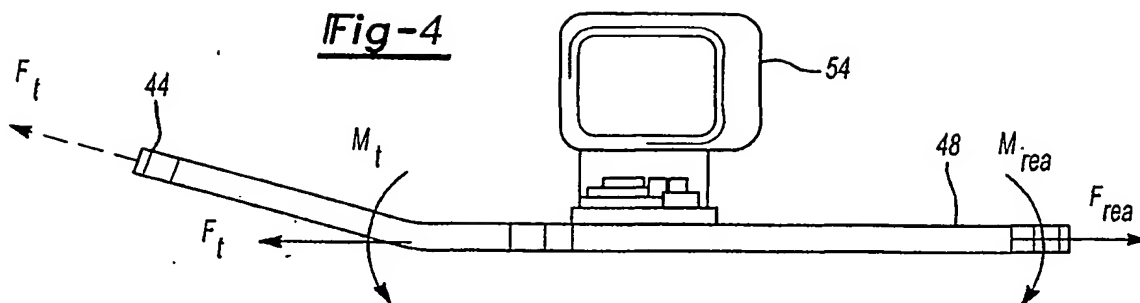
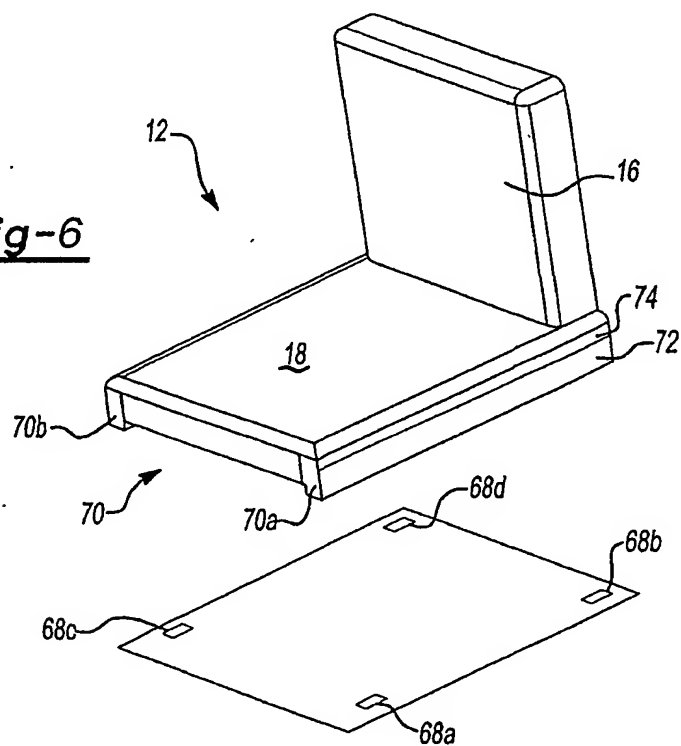
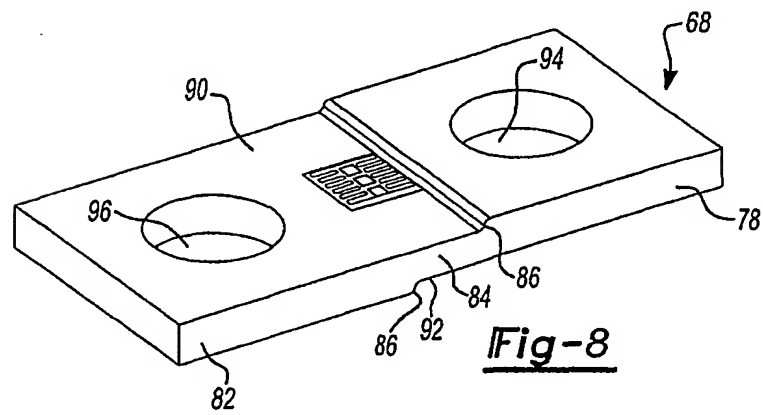
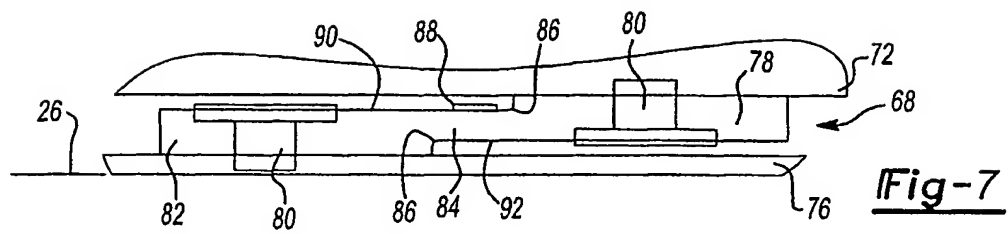


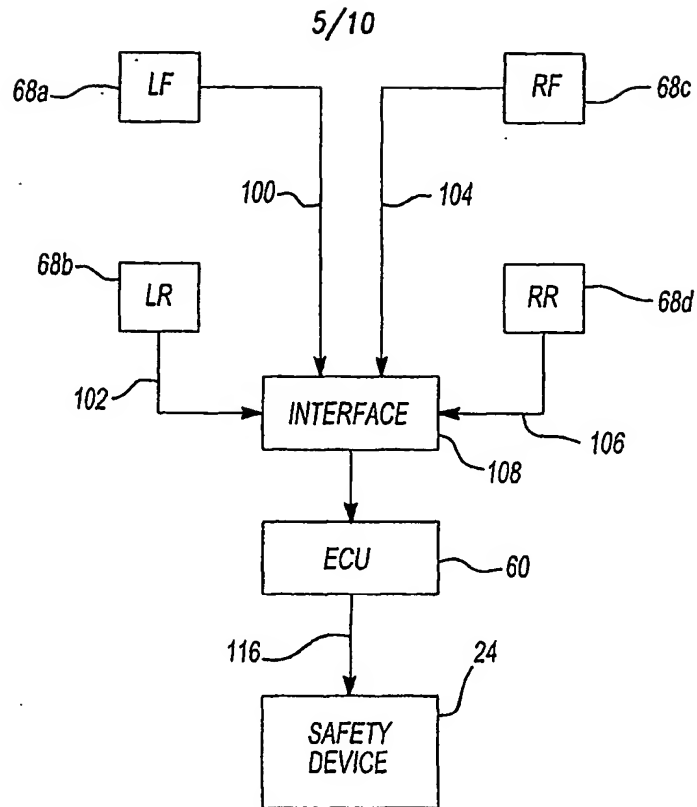
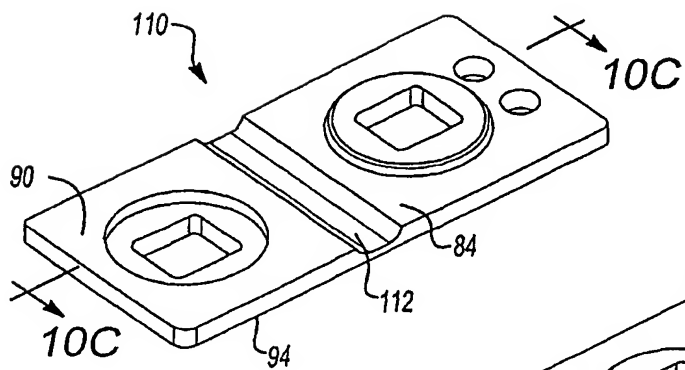
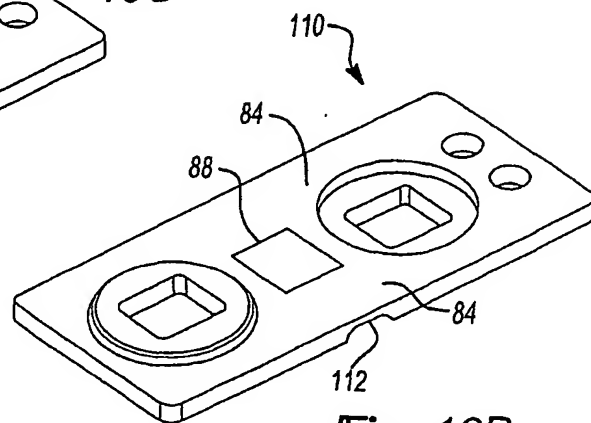
Fig-3

3/10

Fig-4Fig-5Fig-6

4/10



Fig-9Fig-10AFig-10B

6/10

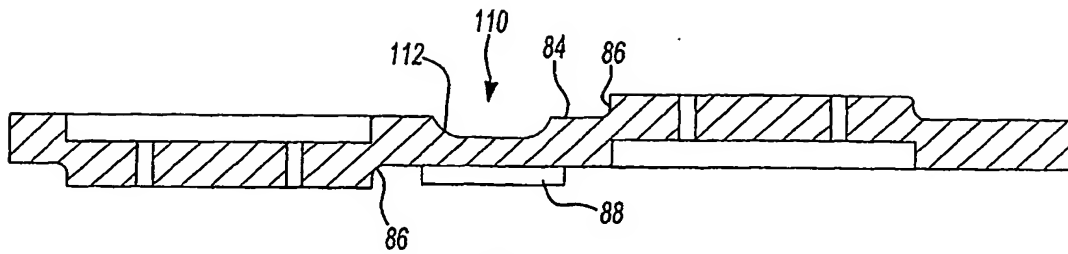


Fig-10C

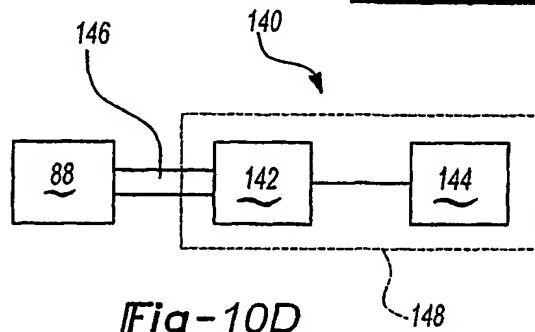


Fig-10D

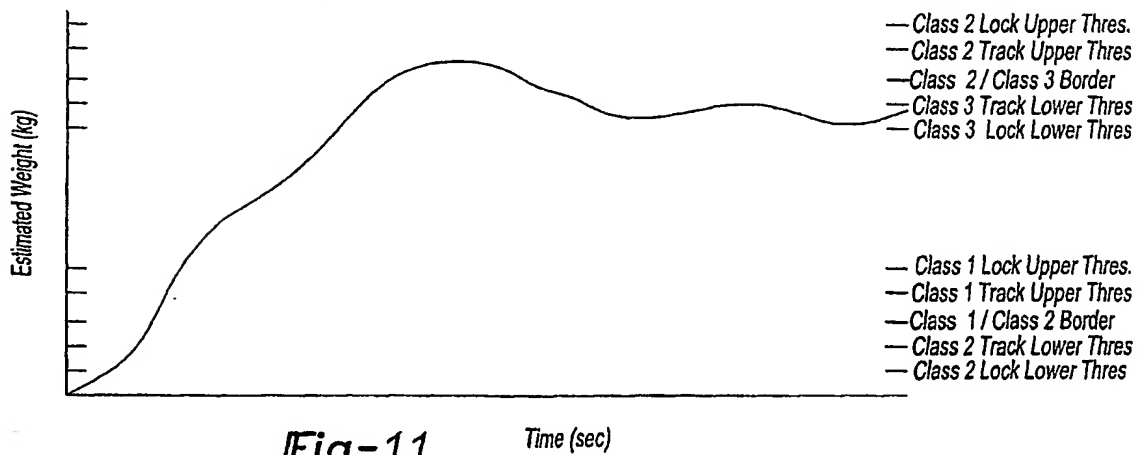


Fig-11

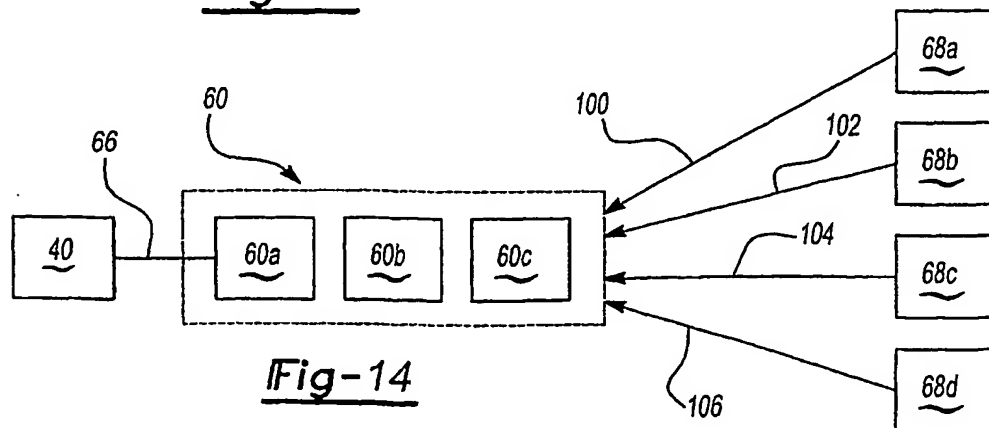
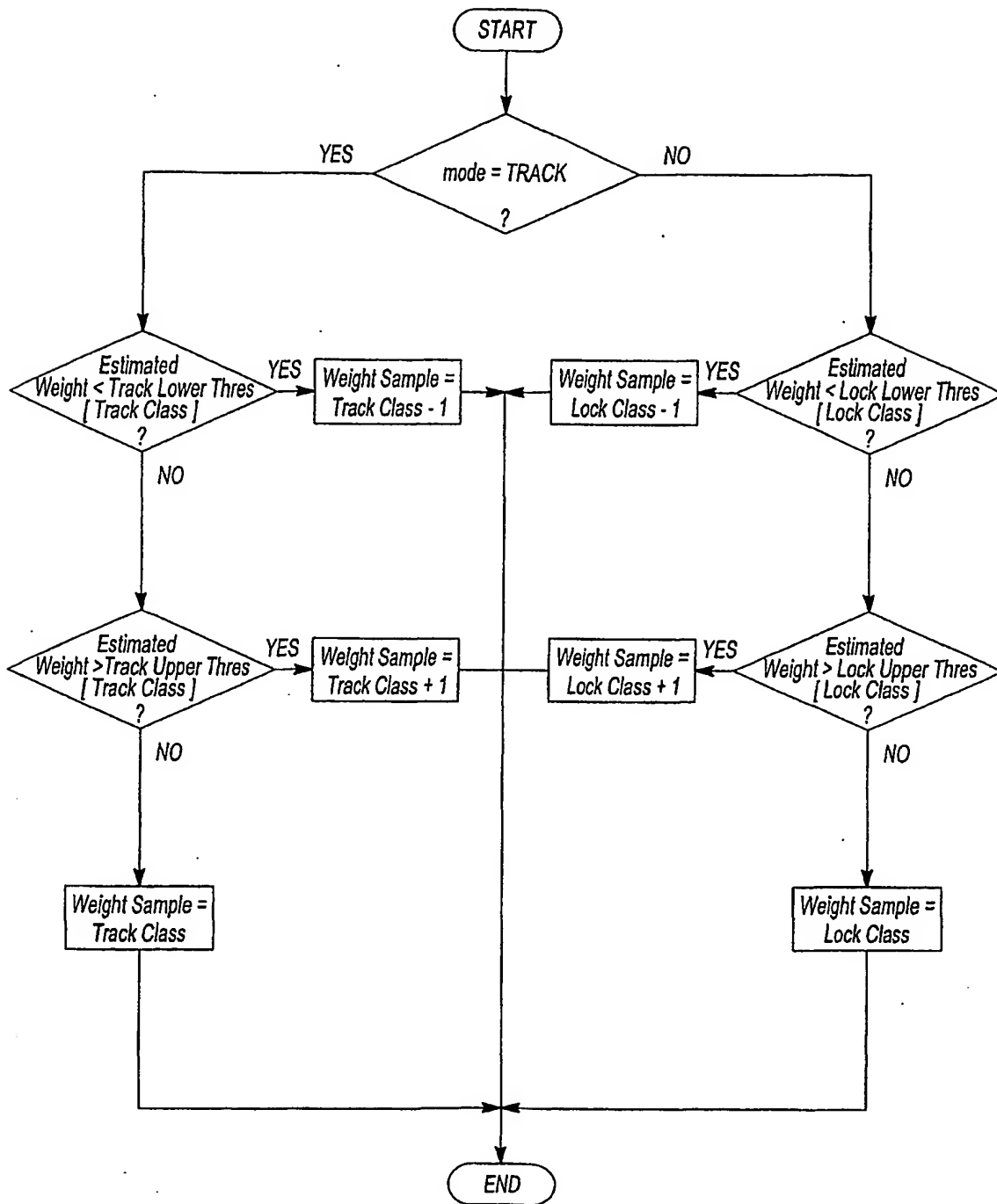


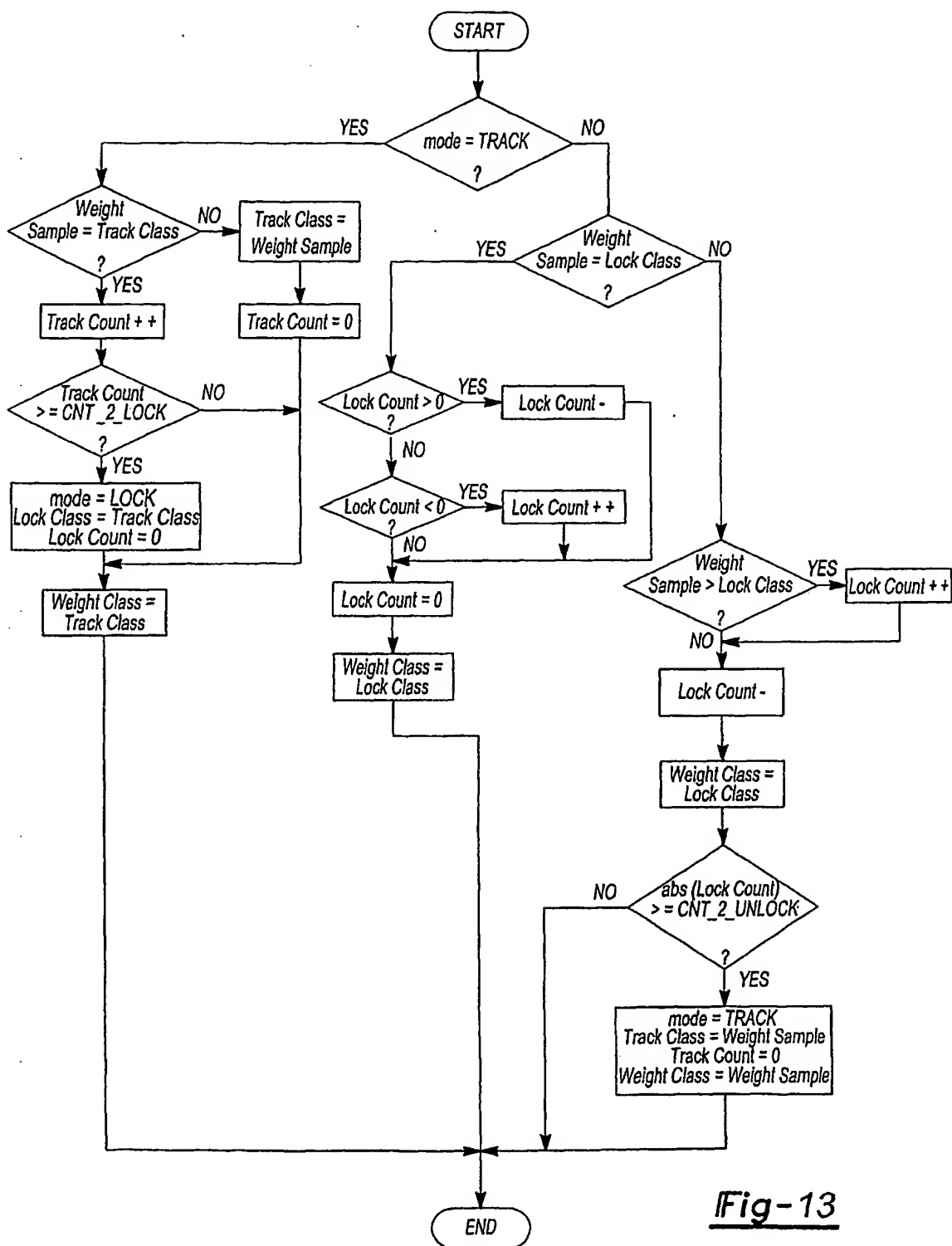
Fig-14

7/10

Fig-12



8/10

**Fig-13**

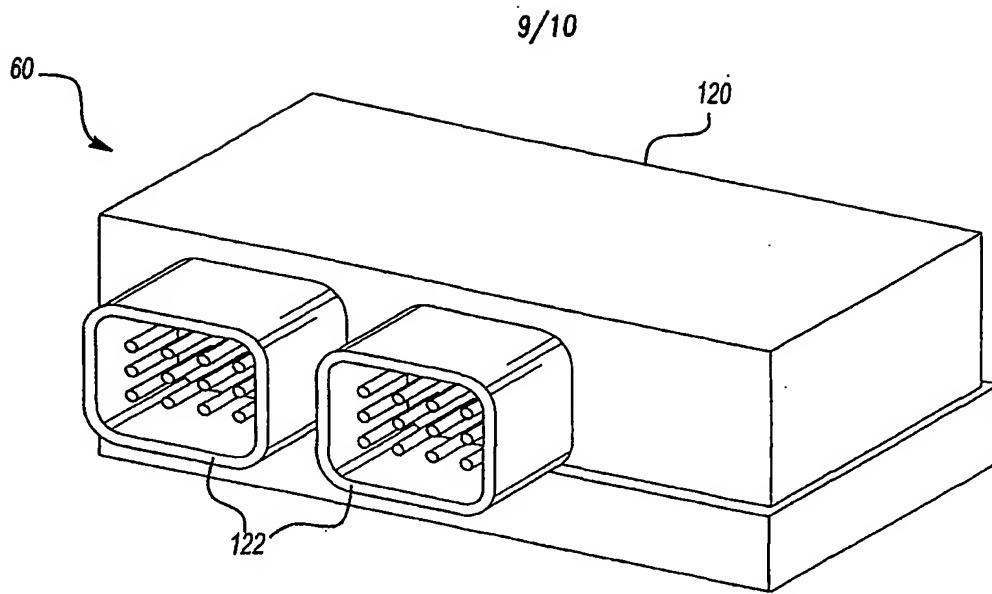
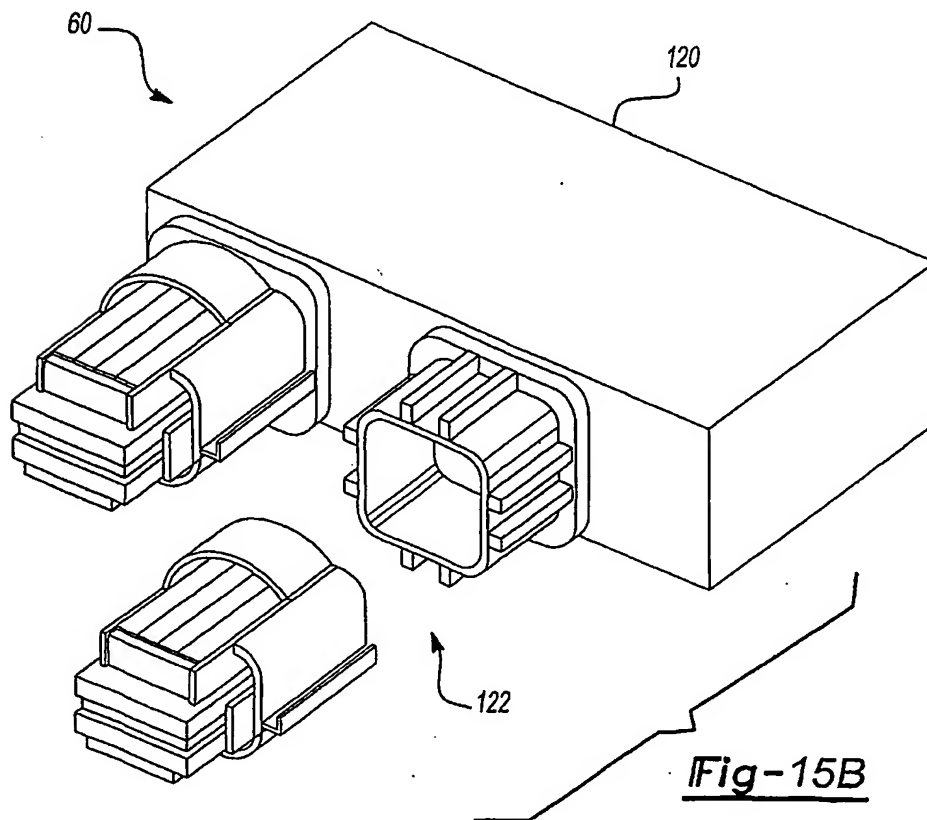
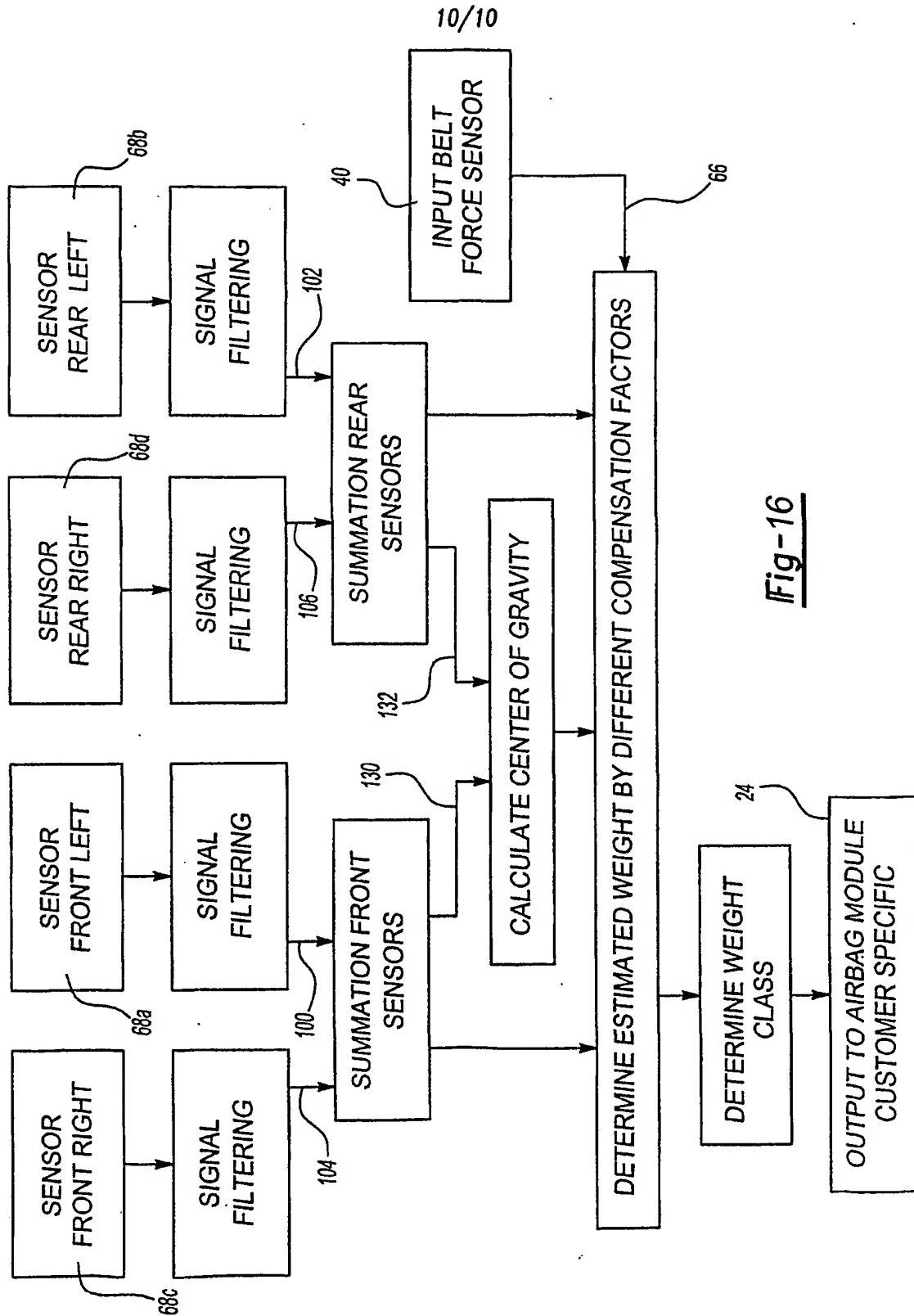


Fig-15A



Fig -16